Optical Transport Technologies and Trends

A Network Planning Perspective

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About BTI

Customers

380+ worldwide in 40 countries, including major carriers and content providers

Offices

Ottawa (Corporate HQ), Boston and with presence in Asia and Europe

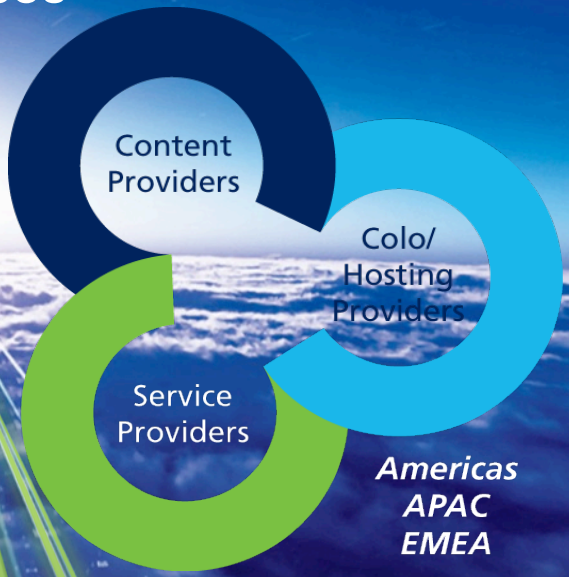
Investors

Bain Capital Ventures, BDC, Covington, GrowthWorks, Fujitsu and others

Portfolio

Networking infrastructure systems & software

BTI delivers software-defined networking infrastructure solutions, enabling global service & content providers to scale their networks & their businesses



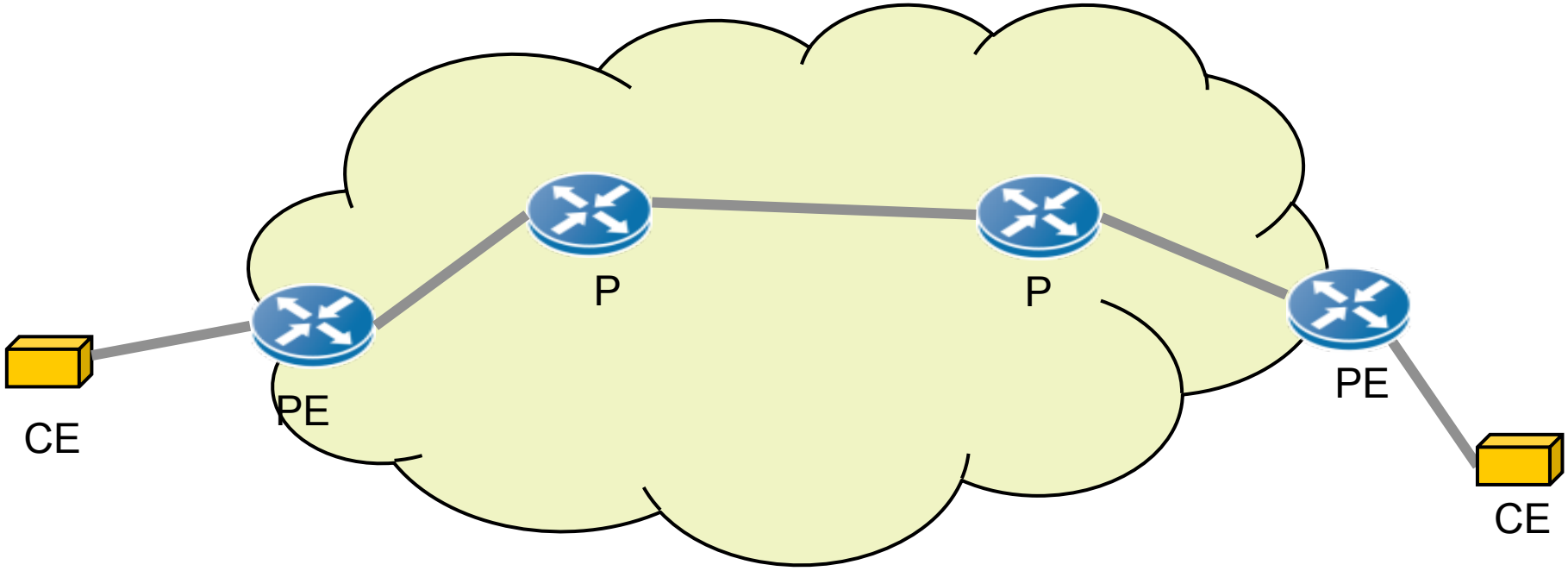
A Quick Show of Hands

- How many of you have designed or engineered an optical transmission link (e.g. CWDM/DWDM)? Or a multiple-node optical transport network?

- How many of you are considering to lease a wavelength or multiple wavelengths in the next 6-12 months?

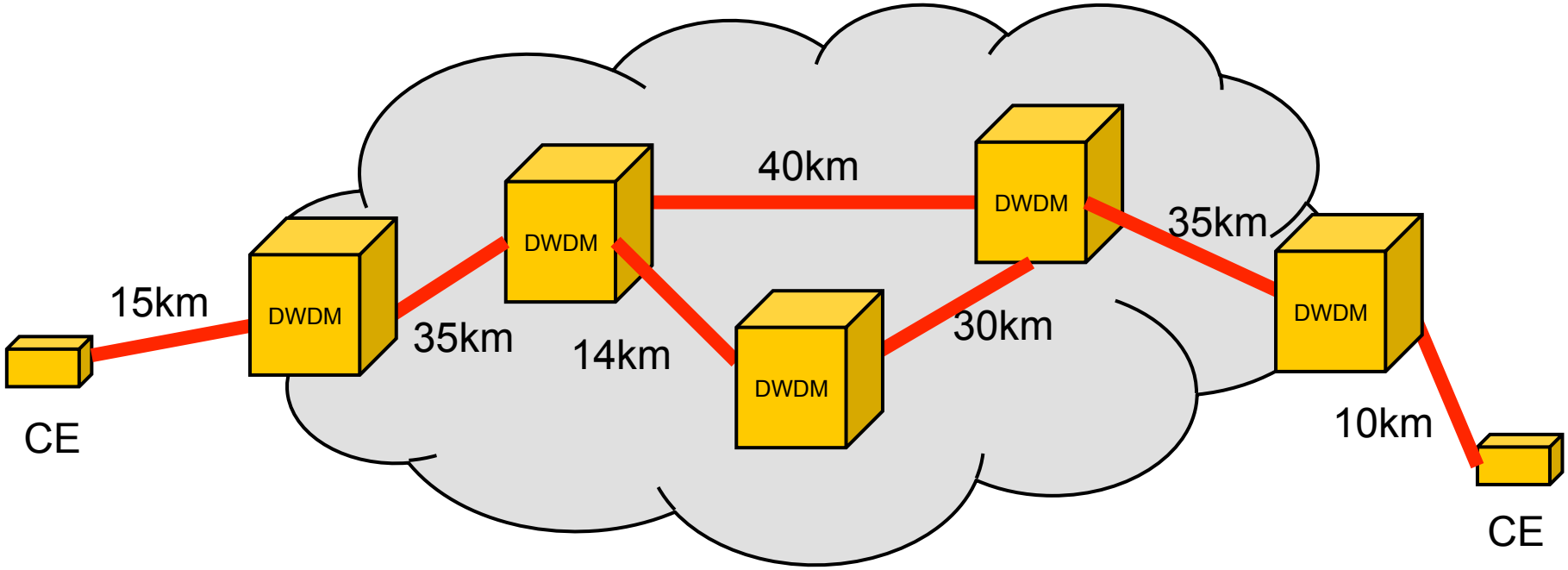
- How many of you are considering to lease a dark (or grey) fiber in upcoming months?

In Data/Packet Networking World…



- Logical connectivity is presented between the routers/switches
- The underlying “physical” network is an abstract layer
- One often requires to know if the routers have 10G, 40G, 100G interfaces and how many of these interfaces are available

In Optical Transport Networking World…



- In optical transmission layer, one needs to know EXACTLY the underlying fiber topology, the fiber details and characteristics, so that the optical layer can be designed accordingly.

From http://www.200churches.com/blog/category/network

List of Questions One Should Always Ask…

1. **Length of the String?**
   - Rack_A to Rack_B (e.g. several meters)
   - Data Center_A to Data Center_B (e.g. tens of km)
   - City_A to City_B (e.g. hundred of km)
2. **Number of the String?**
   - A pair of fiber strands?
   - Multiple pairs?
   - A single (fiber) strand?
3. **Type of the String?**
   - Single mode fiber vs. multi-mode fiber?
   - Common fiber types: G.652 (SMF-28), G.653 (DSF), G.655 (NZDSF)
   - Corning's SMF-28 is commonly used in today's networks

Requirements for Designing Point to Point WDM Link Questions One Should Always Ask…

4. Condition of the String?

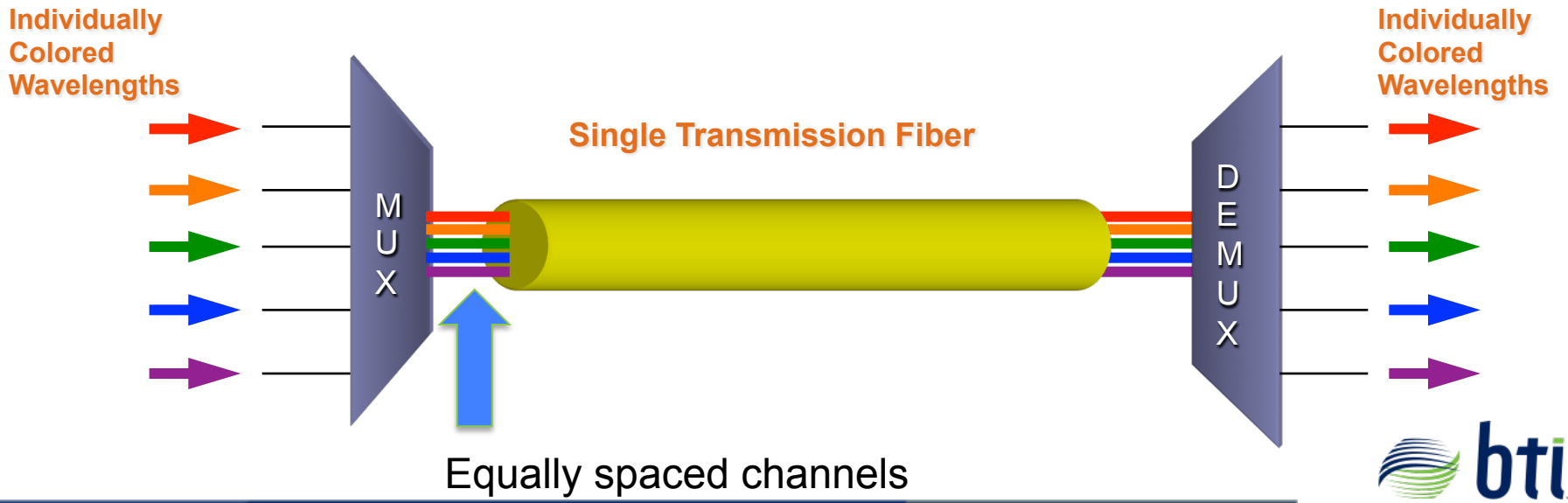
- Any “knots” on the string, wear and tear, etc…
- Any splices or bad connectors on the fiber?
- Amplifiers might be required to recover the “weak” signal due to losses

5. The Sizes of the Cans?

- How big should the pipe be?
- What’s the bandwidth requirement?
- To transport a full 10Gb/s? A full 40Gb/s? Or 100Gb/s?
- To transport multiple full-rate 10Gbps, 100Gbps, even 1Tbps?
- Today, **terabit** of link capacity is no longer a surprise to connect DCs, content providers, or requested by the “Hyper Giants”

Wavelength Division Multiplexing (WDM) –
Similar to Sharing Spectrum over Air, Except Medium here is Fiber

- **Technology Enabler: Wavelength Division Multiplexing**
  - A transmission technology that multiplexes multiple optical carrier signals on a single fiber by using different wavelengths (colors) of laser light to carry different signals of frequencies.
  - Frequency (in THz) and wavelength (in nm) are often used to label a wavelength and the frequency of a signal is inversely proportional to wavelength. e.g. 193 x 10^{12} THz or 1551.9 nm

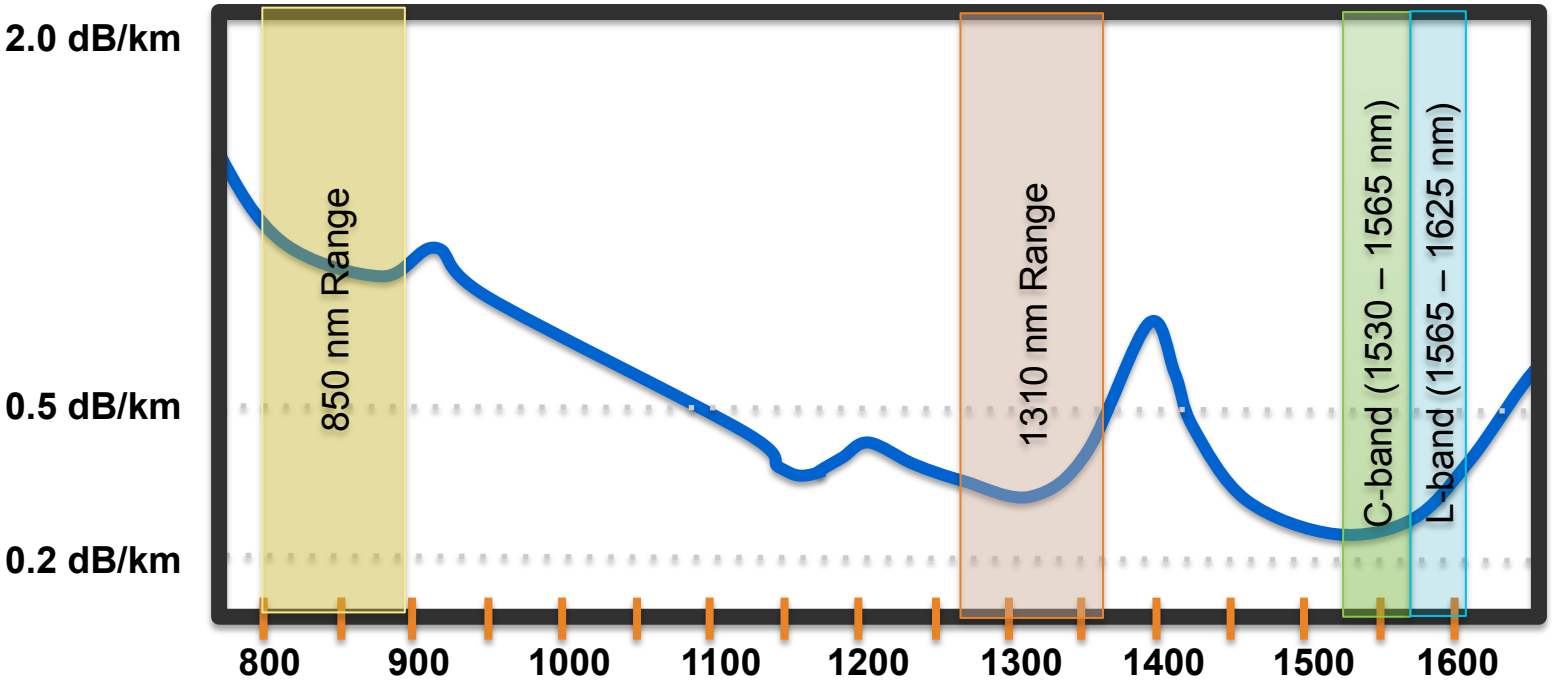


Dealing with Optical Networking…
Fiber Attenuation (measured in dB or dB/km)

- Optical light transmitted through fiber will lose power
- Attenuation caused by Scattering, Absorption and Stress
- Other considerations: fiber length, fiber type, transmission bands, and external loss components such as connectors & splices
- Typical loss: 0.20 dB/km – 0.35 dB/km …
  although I have seen and designed losses as high as 0.5 dB/km
- Total fiber loss + spice loss + connector loss + safety margin
  <= Power Budget

Fiber Impairment:
Attenuation in Optical Fiber (measured in dB or dB/km)

Also known as the three "Transmission" Windows

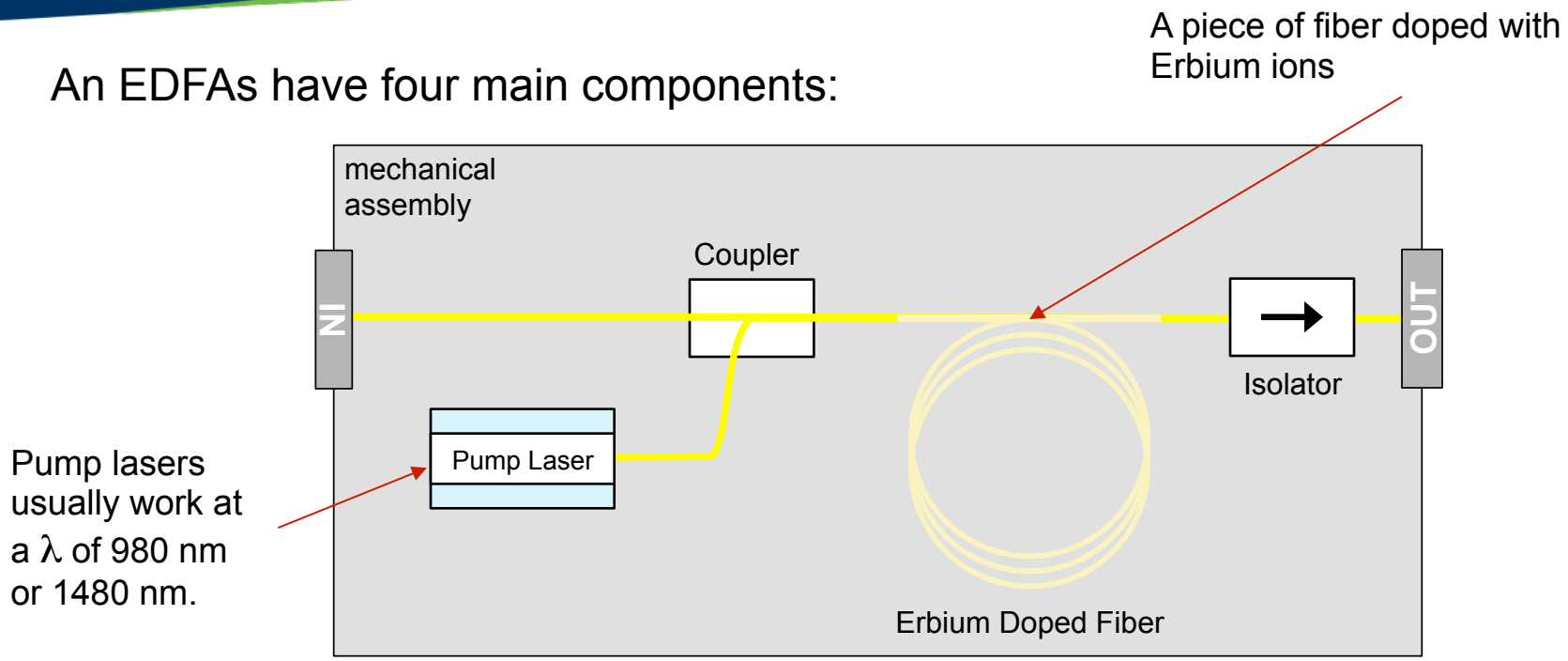


Wavelength in nanometers (nm)

Note: Frequency = 3 x 10^8 / wavelength

To Overcome Fiber Attenuation and Losses… Erbium Doped Fiber Amplifiers (EDFA)

An EDFAs have four main components:

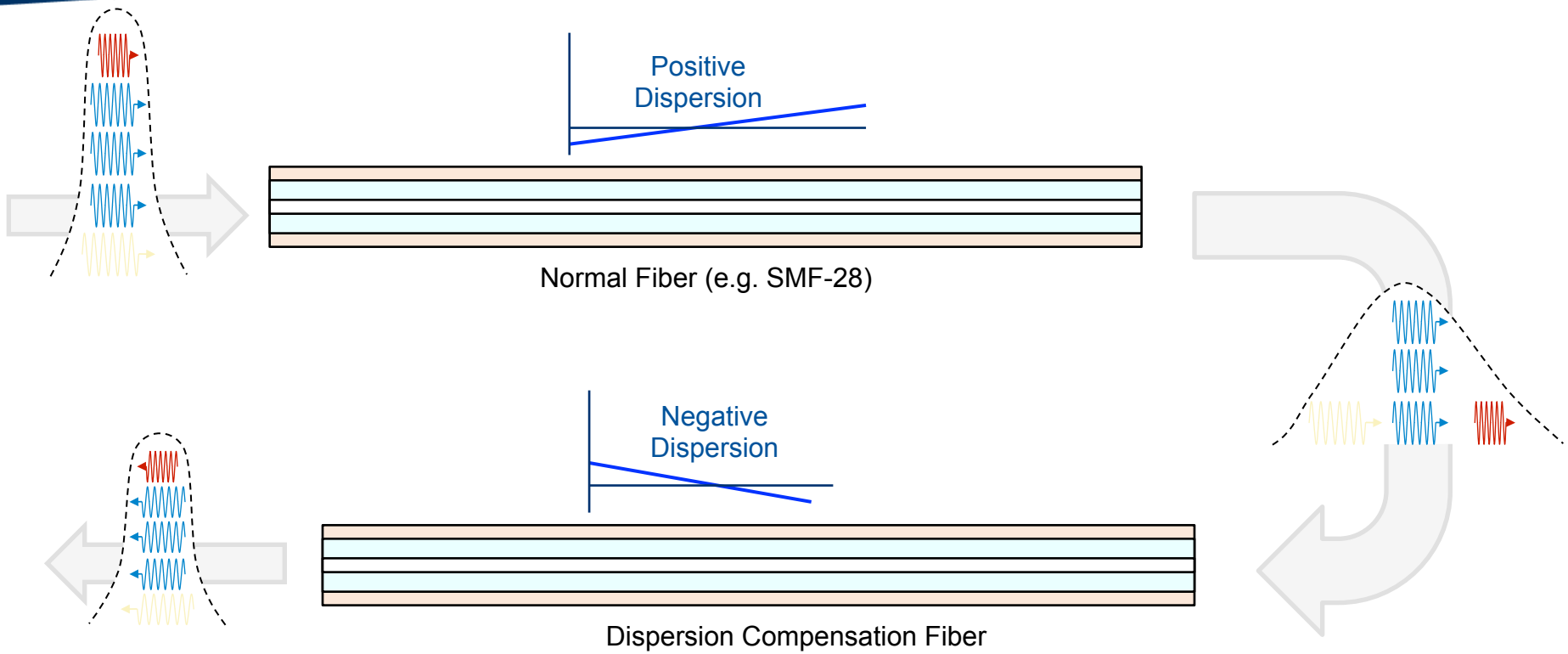


- EDFA is the most widely used amplifiers to compensate for losses
- Usually works in the C-band (L-band is also commercially available)
- Fixed gain amplifier and variable gain amplifier are available
- Up to 35 dB of gain can be supported (via 2-stage of amplification)

Dealing with Optical Networking…
Chromatic Dispersion (measured in ps / km-nm)

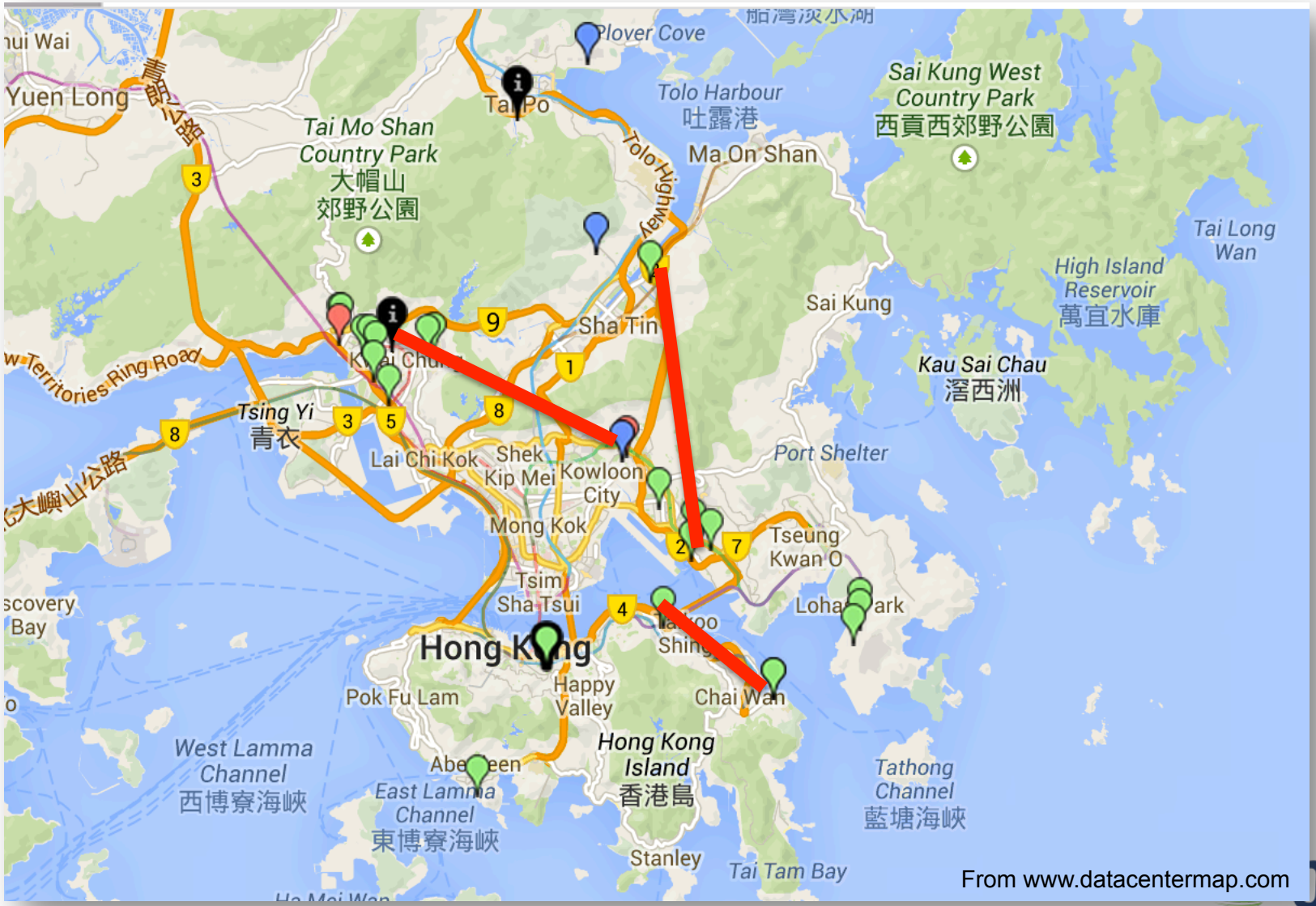
- Different wavelengths travel at different speeds through a given fiber causing optical pulses to broaden or to “spread”
  - e.g. Wavelength Channel #1 travels faster than Channels #2, #3, etc..
- Excessive spread can cause pulses to overlap, and therefore receivers would have a hard time to distinguish overlapped pulses
- The longer the distance (or the higher the bitrate) is, the worst the spread would be.

To Overcome Chromatic Dispersion… Dispersion Compensating Fiber (DCF)



- A normal fiber with positive-slope dispersion makes different wavelengths travel at different speeds from point A to Z
- By passing the wavelengths through a “negative-sloped” dispersion fiber reverses the effects of dispersion or the spread
- *Side Effect: DCF adds extra losses and latency to the transmission*

The Good News is…
To design a point-to-point link in HK is pretty straightforward

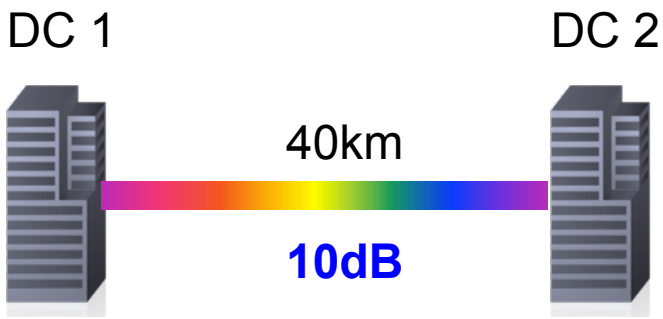


From www.datacentermap.com

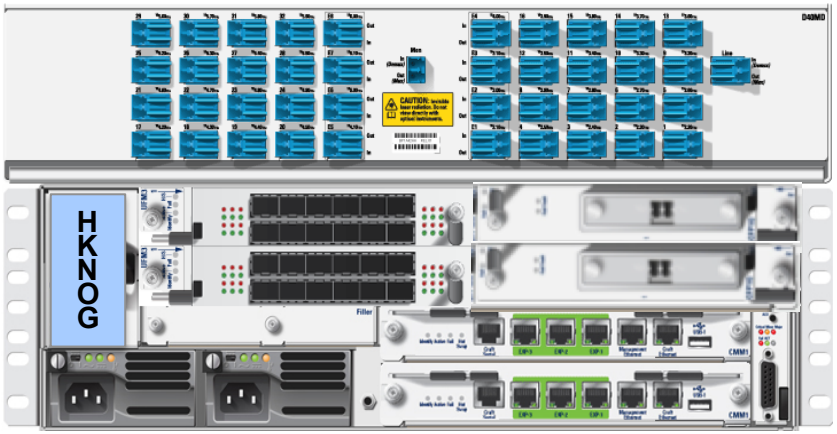
A typical link of 40km between 2 data centers (e.g. 200G) No amplifier and no DCF are required…

Bandwidth Requirement:

20 x 10 GbE or
2 x 100GbE



A Sample Configuration (in 5 RU):



Mux/Demux

Transponder with Pluggable Transceivers

Additional Lego Blocks
Common Mux/Demux Selections from most vendors…

DWDM Mux-Demux (96λ Add-Drop)

DWDM Mux-Demux (40λ Add-Drop)

DWDM Mux-Demux (8λ Add-Drop)

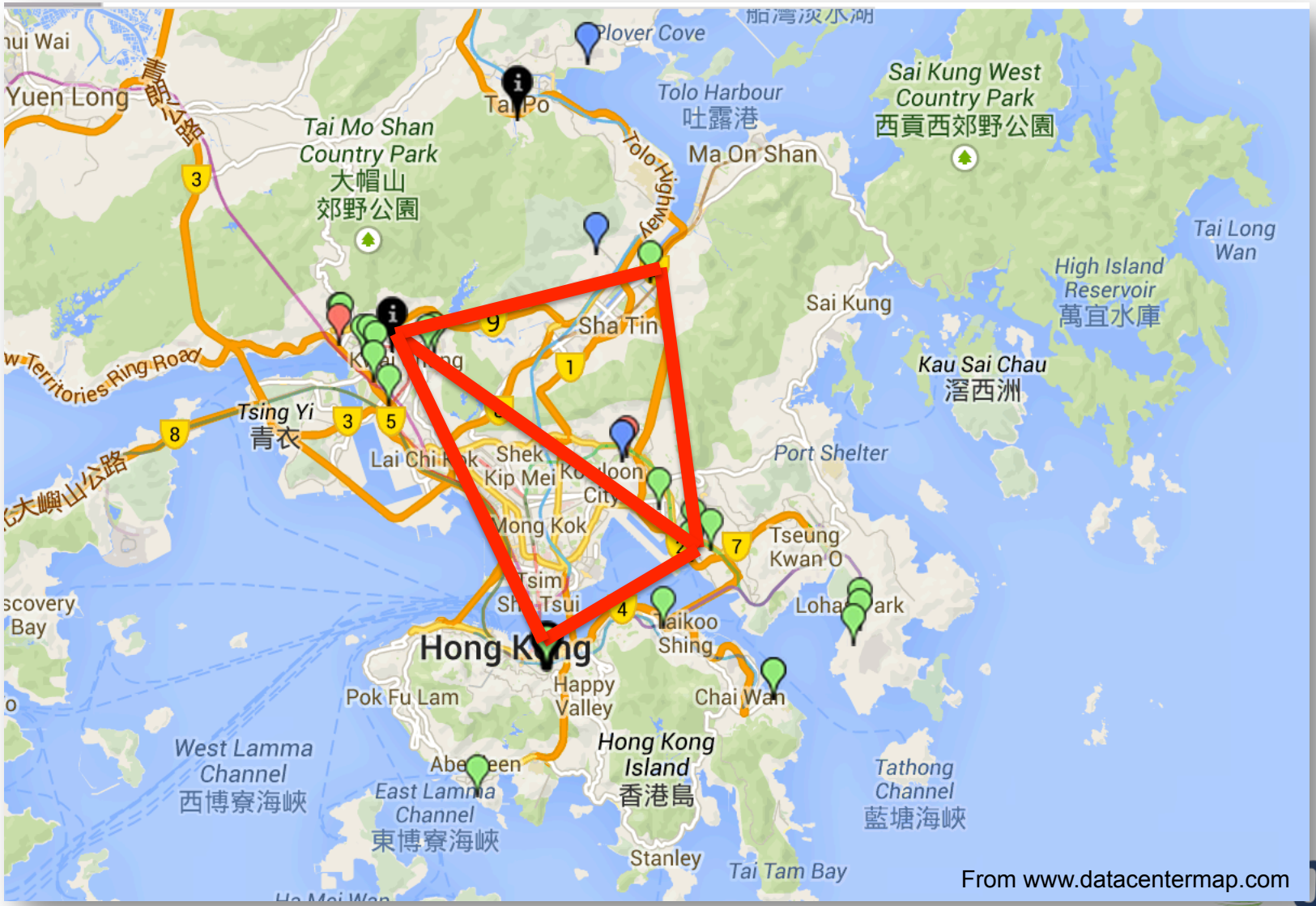
CWDM Mux-Demux (4λ Add-Drop)

OADMs (1,2, and 4λ Add-Drop)

- **Multiplex / Demultiplexer (aka. Mux/Demux) Comes with Various Sizes…**
  - Use light's reflection and refraction properties to separate and combine wavelengths from a fiber strand (e.g. logically think of a prism)
  - Common technologies: thin film filters, fiber bragg gratings and arrayed waveguides (AWG)
  - Passive device which requires no power
  - Higher the channel counts means higher the insertion loss

For More Complex Fiber Topology…

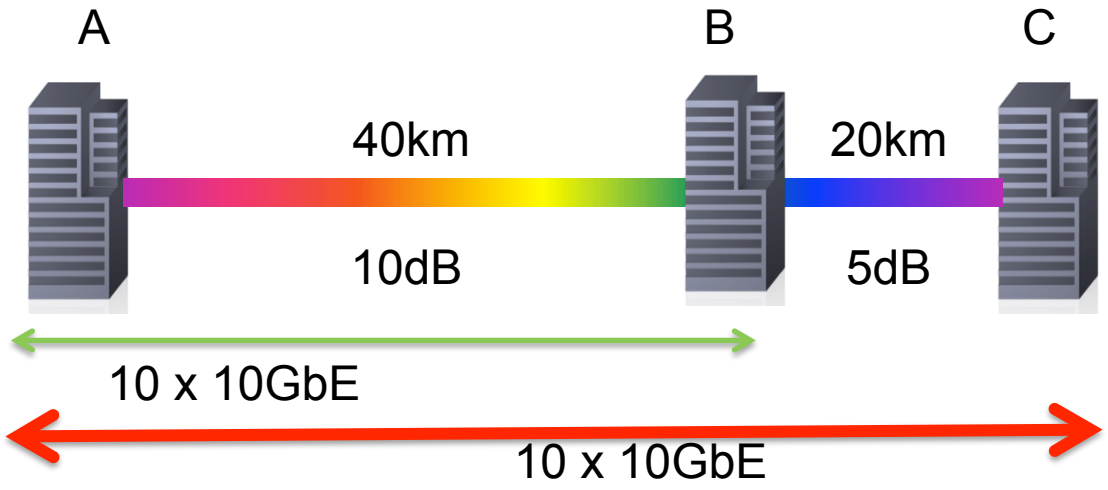
Advanced Technology Enabler Makes Optical Engineering Simpler



From www.datacentermap.com

With Point to Point Fixed Mux/Demux Architecture…

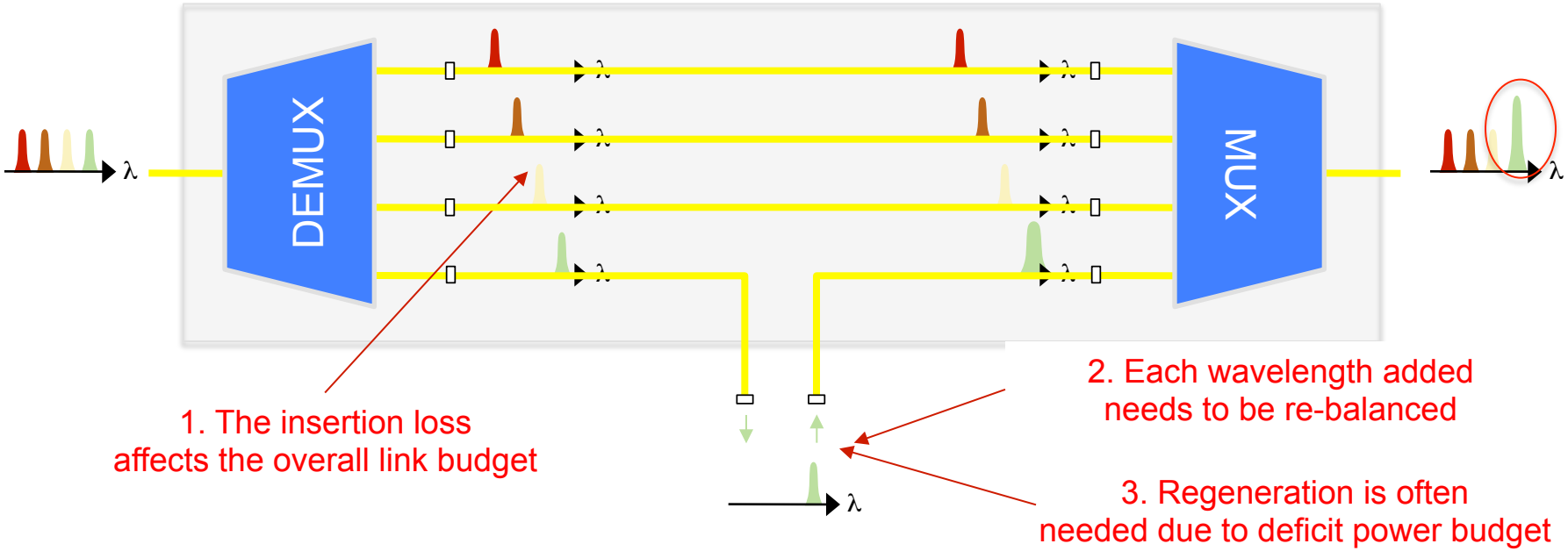
Wavelengths passing through some intermediate sites is always tricky to engineer



- 10 x 10GbE circuits are now between Site A and Site B
- 10 x 10GbE circuits are now between Site A and Site C **(via Site B)**
- For initial Point-to-Point network, Fixed OADM (FOADM) network architecture worked fine.
- A problem arises when we have intermediate location that requires "partial" adding/dropping of traffic → manual patch work is needed

A Closer Look: Channel Patching Work is Required Intermediate Site (at Site B)

From Site A **Via Site B** **To Site C**

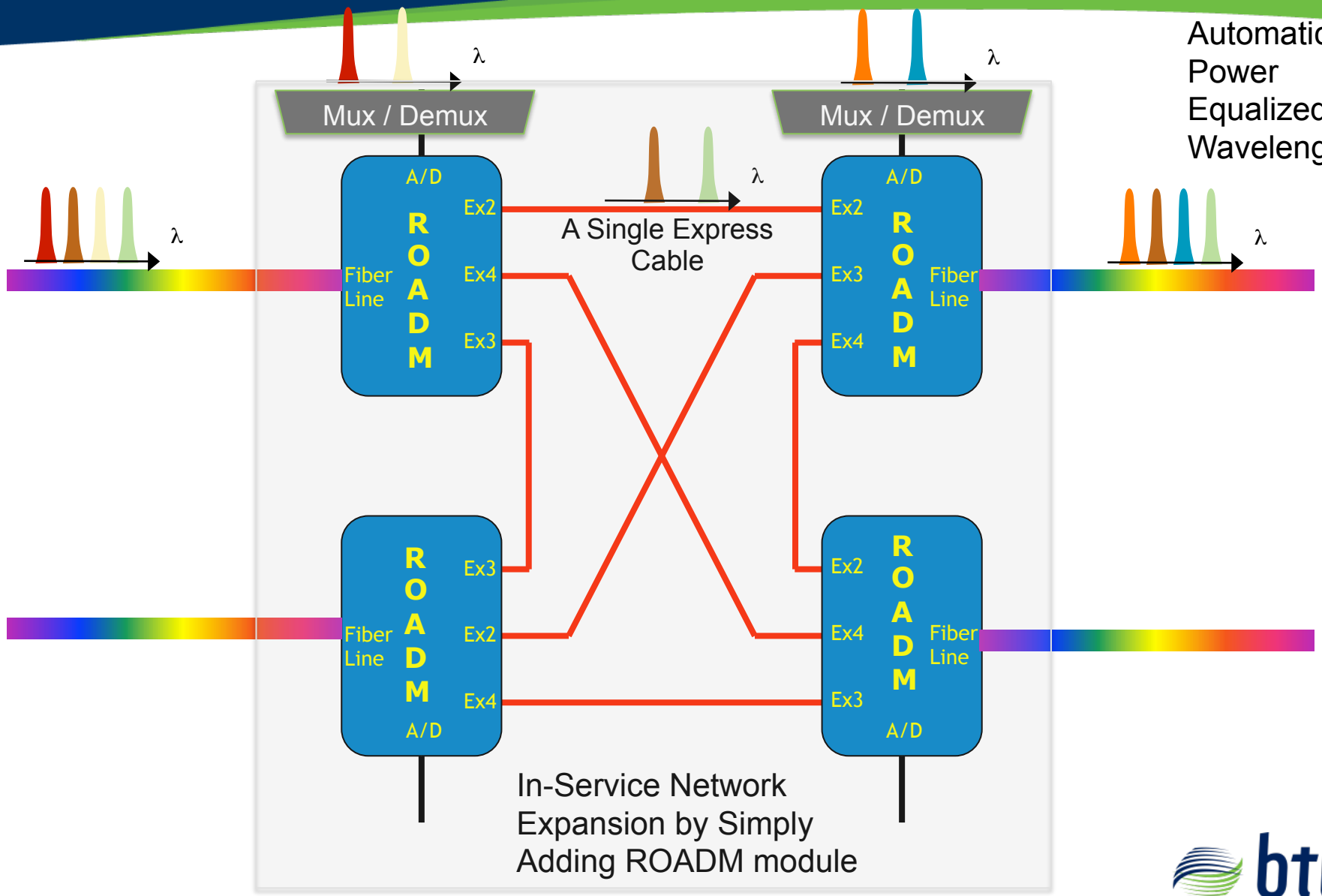


- Since not all wavelengths need to be dropped, manual padding, patching works are required to connect wavelength across intermediate site(s)
- Patching through makes sense for small λ counts, but with 40/96 DWDM channels, this can be prone to human errors and difficult to manage – a better solution is warranted.

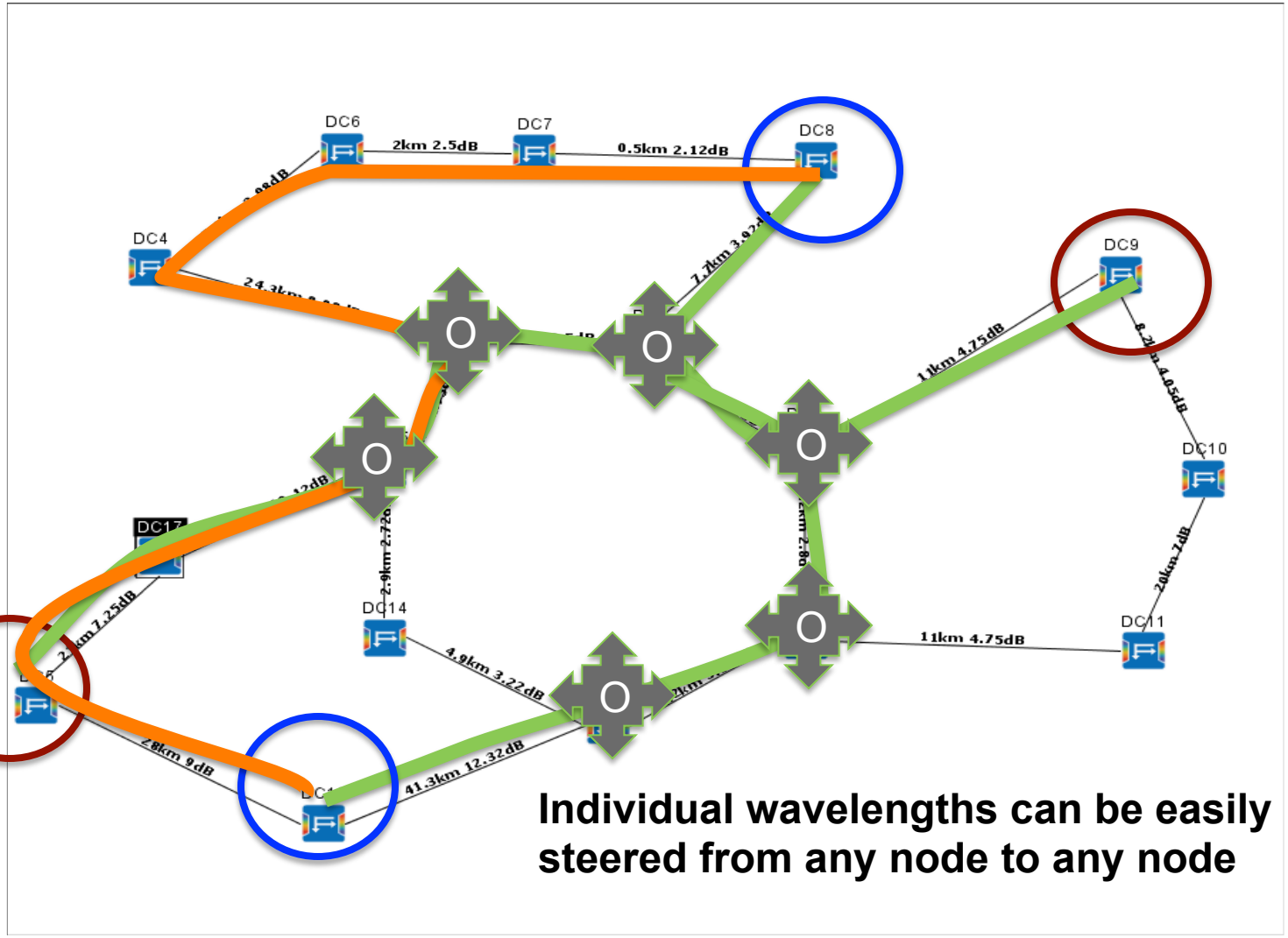
To Overcome Such Complex Engineering… ROADM Technology was Introduced

- **Key Functional Block: Wavelength Selective Switch (WSS)**
  - The ability to switch any input wavelength to any of its output ports
  - The ability to adjust & attenuate power of input and output ports
- The ability to allow adding/dropping of any individual λs
- In some implementations, **additional variable gain amplifier and optical monitoring functions** are added into a single mechanical package:
  - Include EDFAs to compensate for any variable span loss
  - Per-channel power equalization and power monitoring

How a 4-Degree ROADM Node Works…



Network-wide Benefit of ROADM: Reconfigurability, Flexibility and Ease of Expansion



Thank You and Please Drop by the BTI Booth….

- **Key Takeaway: Designing an optical network can be easy**
  - Fiber distance, loss, types, bandwidth requirement are important elements for any optical network design
  - Amplifier, dispersion compensation fibers, mux/demux are key lego blocks
  - ROADM technology adds flexibility and reconfigurability to optical transmission layer
- **Additional BTI's seminar sessions are available upon request:**
  - ✓ "Designing ultra-low latency transmission network for HFT"
  - ✓ "100G optical transmission technologies and designs"
  - ✓ "Data center interconnection – Terabit and beyond"
  - ✓ "Service-assured metro Ethernet networking"
- **Feedback, comments are welcome: dleung@btisystem.com**

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